LITANI RIVER BASIN MANAGEMENT SUPPORT PROGRAM

FEASIBILITY STUDY FOR CONSTRUCTED WETLANDS IN THE LITANI RIVER BASIN

February 2012
This report was produced for review by the United States Agency for International Development (USAID). It was prepared by International Resources Group (IRG) under Contract EPP-I-00-04-00024-00 order no 7.

LITANI RIVER BASIN MANAGEMENT SUPPORT PROGRAM

FEASIBILITY STUDY FOR CONSTRUCTED WETLANDS IN THE LITANI RIVER BASIN

Contract No.: EPP-I-00-04-00024-00 order no 7.

FEBRUARY 2012

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

Figures

Tables

EXECUTIVE SUMMARY

This feasibility report assesses the potential for constructed wetlands to improve water quality in the Litani River Basin, Lebanon. The Litani River Basin is essential for agriculture, urban development, industry in Lebanon and suffers from widespread water pollution due to lack of pollution regulation and enforcement, few operable wastewater treatment facilities, and environmentally damaging agricultural practices. The major sources of water pollution in the basin are wastewater releases from domestic, industrial and agricultural sources as well as solid wastes and leachates.

Treatment wetlands are systems that harness physical, chemical, and microbial processes found in natural wetland environments to remove pollutants from wastewater. The systems have been in use for over 60 years and have seen widespread advancement in the past two decades as a viable option for controlling water pollution with little to no conventional energy input and potential for greatly reduced operations and maintenance demands relative to traditional technologies. These aspects combined with their wide applicability to different implementation scales and pollutant types make them well-suited for the Litani River Basin. Additionally, treatment wetlands offer significant potential for environmental education, passive recreation, and restoration of wildlife habitat that other more conventional systems lack.

NewFields conducted reconnaissance in the Litani River Basin and identified four potential treatment wetland sites. These were evaluated for their logistical, technical, and engineering feasibility and preliminary wetland concepts and cost estimates were developed for each site. Based on their comparative strengths and weaknesses, a preferred site was chosen that offers the best potential for satisfying the goals of this pilot treatment wetland project under the LRBMS. The four sites evaluated include:

1. The LRA-owned parcel along the Litani River near Joub Jannine (**Preferred Site**): this site offers plenty of available land adjacent to the Litani River, public ownership, and proximity to an untreated wastewater outfall. A treatment wetland sited here would provide improved water quality downstream to Qaraoun Lake and Canal 900. Because the site is adjacent to an existing LRA water management center, and 10 km away from Lebanon's only remaining natural wetland (Aammiq), this site offers significant potential for environmental education, wetland habitat restoration, and other ancillary benefits.

   We have developed a preliminary plan for an approximately 3.5 ha treatment wetland facility expected to cost approximately $363,000.

2. The Tannayel dairy farm offers two potential options for treatment wetlands. One opportunity would treat diverted water from the Chtaura River that feeds an on-site lake that is used for irrigation water storage. This wetland would improve water quality used to irrigate crops on the farm by converting a corner of the lake into a treatment wetland and increasing habitat diversity in the process. The second opportunity would treat dairy production wastewater that is currently disposed of in a septic system.

   The proposed irrigation water treatment system would occupy approximately 5000 m^2 and cost approximately \$379,000. The dairy treatment wetland would occupy 1 hectare and cost approximately \$96,000.

3. The Liban Lait dairy farm is Lebanon's largest dairy farm and currently pipes over 500 m^3/d of high-strength wastewater directly to the Litani River. A pilot-scale treatment wetlands to remove organic matter and nutrients from this point source discharge could be created as a demonstration that might eventually lead to wetland treatment of all produced wastewater at the facility.

   This pilot-scale system would occupy approximately 2 hectares, treat 10-20% of the total daily wastewater load, and cost approximately \$186,000.

4. The Berdaouni River above the city of Zahle flows through a series of cafés which are designed for outdoor seating on the river. During the summer months, untreated domestic wastewater from upstream causes a malodorous condition in the river that impacts the cafés business. Upstream of the cafés, a small number of floodplain terraces exist that have been developed as small-scale agricultural fields. One or more of these could be converted to a wetland system that receives diverted river water, removes pollutants, and discharges back into the river and may alleviate the odor problems.

   A 3000 m^2 terrace was evaluated for implementation as a treatment wetland system and is estimated to cost \$68,000.

The Joub Jannine site was selected as the preferred alternative because it maximizes the available budget for a LRBMS-sponsored pilot treatment wetlands system as well as the water quality benefit to the Litani River Basin. Because of the available size of land, the system may be able to treat most or all of the flow in the Litani River during the summer when water quality is poorest. And it offers significant potential for ancillary benefits that the other evaluated sites do not.

To further develop this preferred site, additional data collection must take place and the concept must be refined into a set of design plans and specifications. This is planned to occur in the early spring of 2012 with eventual construction in the fall of 2012.

ملخص تنفيذي

يقيم هذا التقرير الجدوى المحتملة للأراضي الرطبة التي شيدت لتحسين نوعية المياه في حوض نهر الليطاني، لبنان. يستخدم حوض نهر الليطاني للاغراض الزراعية، والتنمية الحضرية، والصناعة في لبنان، حيث يعاني هذا الحوض من تلوث المياه على نطاق واسع نظرا لعدم وجود قواعد لتنظيم التلوث وفرض تطبيق الانظمة والقوانين، كذلك وجود عدد قليل من محطات تكرير مياه الصرف الصحي القابلة للتشغيل، ناهيك عن الممارسات الزراعية الضارة بيئيا. ان المصادر الرئيسية لتلوث المياه في حوض الليطاني هو تدفق مياه الصرف الصحي المنزلي والملوثات السائلة الصناعية والزراعية وكذلك النفايات الصلبة ومياه الرشح.

إن الأراضي الرطبة المخصصة لمعالجة المياه، تقوم بتسخير البكتيريا الطبيعية الموجودة فيها لإزالة الملوثات الفيزيائية والكيميائية، والجرثومية من مياه الصرف الصحي. ان هذا النظام يتم استخدامه لأكثر من ٦٠ عاما، وشهدت منذ ذاك الحين تقدم على نطاق واسع خصوصاً في العقدين الماضيين كخيار قابل للتطبيق للتحكم في تلوث المياه من دون استخدام كثيف للطاقة التقليدية كما وهناك إمكانية لتقليص إلى حد كبير عمليات الصيانة الذي يتطلب نسبة من التكنولوجيات التقليدية. هذه المظاهر الطبيعية والقدرات العلاجية لهذه الاراضي تتلاقى مع بعضها حيث يمكن تطبيقها على نطاق واسع لمعالجة مختلف أنواع الملوثات وجعلها مناسبة تماما لحوض نهر الليطاني. بالإضافة إلى ذلك، فالأراضي الرطبة المعالجة توفر إمكانات كبيرة للتعليم البيئي، والترفيه السلبي، واستعادة موائل الحياة البرية أكثر من النظم التقليدية الأخرى التي تفتقر إلى ذلك.

تم اجراء استطلاع لاماكن جديدة في حوض نهر الليطاني وحددت أربعة مواقع لأراضي العلاج الرطبة المحتملة. حيث تم تقييمها من الناحية الوجستية والتقنية، ووضعت الجدوى الهندسية لها والمفاهيم الأولية وتقديرات التكلفة لكل موقع. وبناءً على نقاط القوة والضعف النسبية، تم اختيار الموقع المفضل الذي يوفر أفضل إمكانيات لتلبية أهداف هذا المشروع "أراضي العلاج الرطبة" الرائدة في إطار ال LRBMS. تحتوي الاربعة اماكن المقيّمة على ما يلي:

١. الارض المملوكة من المصلحة الوطنية لنهر الليطاني على طول نهر الليطاني قرب جب جنين (الموقع المفضل): هذا الموقع يقدم الكثير من الأراضي المتاحة المتاخمة لنهر الليطاني، والملكية العامة، والقرب إلى مصبات مياه الصرف الصحي غير المعالجة. أرض العلاج الرطبة في هذا المكان من شأنها أن توفر تحسين جودة المياه عند المصب إلى بحيرة القرعون والقناة ٩٠٠. لأن الموقع مجاور لمركز إدارة المياه التابع للمصلحة الوطنية لنهر الليطاني والموجود على بعد ١٠ كم من الأراضي الرطبة الطبيعية الوحيدة المتبقية في لبنان (عميق)، هذا الموقع يوفر إمكانية كبيرة للتعليم البيئي، و واستعادة موائل الأراضي الرطبة، والمزايا الإضافية الأخرى.

وقد وضعنا خطة أولية لأراضي العلاج الرطبة على مساحة ما يقارب ٣,٥ هكتار والمتوقع أن تكلف ما يقرب من ٣٦٣٠٠٠ $.

٢. تقدم مزرعة الألبان "تعنايل" فرصتين او الاستفادة من معالجة امرين خطيرين على البيئة. الفرصة الاولى هي معالجة المياه المحولة من نهر شتورة الذي يغذي البحيرة الصغيرة في الموقع المذكور الذي يتم استخدامها لتخزين

مياه الري. ان انشاء اراض العلاج الرطبة في هذا المكان من شأنه أن يحسن نوعية المياه المستخدمة في ري المحاصيل في المزرعة عن طريق تحويل الزاوية من البحيرة إلى أراضي علاج رطبة وزيادة تنوع الموائل في هذه العملية. اما الفرصة الثانية فهي لعلاج المياه الناتجة من عملية تصنيع الالبان ومشتقاتها التي يتم التخلص حاليا منها في نظام الصرف الصحي العام.

ان نظام معالجة مياه الري المقترحة تحتل حوالي ٥٠٠٠ متر مربع وستكلف حوالي ٣٧٩٠٠٠ $. اما اراضي العلاج الرطبة لناتج عملية تصنيع الألبان التي ستحتل ١ هكتار مع كلفة تقريبية ٩٦٠٠٠$.

٣. تعتبر مزرعة "اليبون ليه" مزرعة الألبان الأكبر في لبنان وتصرف أنابيبها حاليا أكثر من ٥٠٠ متر مكعب / يوميا من مياه الصرف الصحي عالية التلوث مباشرة إلى نهر الليطاني. يمكن إنشاء أراض العلاج الرطبة على نطاق تجريبي او نموذجي لإزالة المواد العضوية والمواد المغذية من هكذا نوع من المصادر، والتي يمكن ان تعالج الصرف الصحي المنتج في هذه المنشأة.

سيحتل هذا النظام التجريبي حوالي ٢ هكتار، حيث سيتم معالجة ١٠-٢٠٪ من إجمالي مياه الصرف الصحي المنتجة يوميا، وتكلف حوالي ١٨٦٠٠٠ $.

٤. يقع نهر البردوني في وسط مدينة زحلة ويتدفق بين سلسلة من المقاهي التي صممت خصيصاً للجلوس في الهواء الطلق على ضفاف النهر، حيث تسبب مياه الصرف الصحي المنزلية غير المعالجة المتدفقة في مجرى النهر نفسه خلال أشهر الصيف، تسبب روائح كريهة من النهر والتي تؤثر على عمل المقاه، كما وان بعض الحقول الزراعية صغيرة الحجم تتأثر من تلك المياه غير المعالجة، لذلك يمكن تحويل بعض من هذه الحقول إلى اراض علاج رطبة(wetland)، وتحويل مياه النهر اليها لمعالجتها وازالة الملوثات منها ومن ثم اعادتها إلى مجراها الرئيسي. ان كلفة تحويل ارض بمساحة ٣٠٠٠ متر مربع إلى wetland يساوي تقريباً ٦٨٠٠٠دولار امريكي.

إن اختيار موقع جب جنين لانشاء ال wetlandالمذكورة، حصل لاعتبارات عديدية، اهمها انه يقع في مكان قد يكون الاخير جغرافياً للتلوث قبل بحيرة القرعون وبالتالي معالجة المياه في هذه النقطة سوف يناسب معالجة مياه البحيرة او اقله سوف يساهم بتخفيف الضغط عنها كما وان هذا النظام قادر على معالجة جزء كبير او معظم مياه النهر في فصل الصيف حيث تكون نوعية المياه متدنية جداً، ومع ذلك فان هناك اعتبارات اخرى كتوفر الارض وهذا من اهم الامور التي تؤخذ بعين الاعتبار في بلد كلبنان وتوفر الميزانية المتاحة لاقامة هكذا نموذج عبر مشروع الLRBMS.

1. INTRODUCTION

This document presents a feasibility analysis for development of a constructed treatment wetland system for water pollution control in the Bekaa Valley, Lebanon. The Litani River, which flows through the valley and supports agriculture, urban development, industry, and hydropower generation, is Lebanon's largest river and a primary water resource. Lack of water quality regulation and enforcement, pervasive solid waste and wastewater disposed of in the river, and overuse of fertilizers and pesticides have led to heavy levels of pollution in the wet season (when rainfall is available to dilute stream flows) and complete domination by sewage in the dry season.

While ongoing efforts to construct wastewater treatment plants are occurring, funding is not allocated to operate many such systems and infrastructure improvements are not currently improving basin water quality. The Litani River Authority (LRA) with funding from USAID seeks to demonstrate the viability of a constructed wetland to improve water quality in Litani River with a very low operating cost. This document details the process undertaken to establish wetlands as a viable treatment option, select an appropriate site, and develop a preliminary concept.

1.1. LITANI RIVER BASIN PHYSICAL OVERVIEW

The Litani River Basin is well characterized elsewhere (SPI-Water 2007, LRBMS 2011a, UNDP 2011); therefore, here we provide only a short summary of conditions in the basin that are of specific relevance to evaluation of feasibility for treatment wetland systems.

The Litani River Basin is located in eastern Lebanon. It is bordered on the west and is in the rain shadow of the Mount Lebanon mountain range, and is bounded on the east by the Anti-Lebanon mountain range. The basin is characterized by hot, arid summers and cool, wet winters typical of the Mediterranean region. Winter rainfall, spring snow melt, and artesian groundwater springs throughout the valley provide the river's natural streamflow. Human modifications such as the dam creating Qaraoun Lake in the southern portion of the basin, irrigation canals, pumping and diversions from the river and its tributaries, and significant lowering of the groundwater table through pumping have all impacted the natural hydrology of the river basin.

While the LRA has played a significant role in management of water in the basin, its focus has been on the development and maintenance of hydroelectric power, water supply, and related infrastructure activities. The basin fundamentally lacks an integrated water resource management entity to implement policies, manage data, and plan for future sustainable use of the river as a water resource. Groundwater depletion, severe reduction of in-channel flows in late summer, and a complete lack of treatment of wastewater discharges to the river in the majority of the basin threaten its long-term viability. Urban/industrial discharges are most prevalent in the north of the basin while agricultural discharges are more prevalent in the south. The eventual water quality reaching Qaraoun Lake and in the Litani River itself is therefore poor, and suffer from eutrophication, pollutant accumulation in sediments, and low dissolved oxygen.

Major sources of water pollution in the basin include (LRBMS 2011a, UNDP 2011):

- Domestic wastewater: until 2000, there were no wastewater treatment plants within the Litani River Basin. It has been estimated that 8% of the basin's population use primitive means to dispose of sewage, 42% use septic tanks, and 50% have access to sewage collection system. However, there are a few operating wastewater treatment plants and much collected sewage is directly discharged directly to the Litani River or its tributaries. Primary pollutants in domestic wastewater include:
    - biochemical oxygen demand (BOD) and organic matter,
    - nutrients such as nitrogen and phosphorus,
    - suspended solids, and
    - pathogens such as viruses and bacterial coliforms.
- Industrial wastewater: the northern portion of the Bekaa Valley contains many industries including paper processing, sugar refining, battery recovery, stone cutting, and automobile maintenance and fueling stations. None of these effluents are currently treated and are the source of pollutants such as:
    - heavy metals such as mercury, chromium, and lead,
    - chemical oxygen demand (COD),
    - fine mineral sediments, and
    - oil and grease.
- Agricultural wastewater: much of the Bekaa Valley land area is in agricultural production and overuse of pesticides and fertilizers is common. Additionally, livestock and food production, especially dairy activities, exist and effluents are not treated before discharge to the Litani River and its tributaries. Primary pollutants in agricultural wastewater's include:
    - nutrients such as nitrogen and phosphorus,
    - BOD,
    - pathogens such as viruses and bacterial coliforms, and

    - pesticides.

- Solid wastes and leachates: many unauthorized solid waste dump sites exist throughout the Bekaa Valley and are frequently found adjacent to river courses. These present a significant solid waste load to the river but also produce contaminated leachates.

Design of a treatment wetland in the Litani River Basin will require that certain data be available to lay out the facility, develop a water balance and predict treatment performance. These data and their availability in the Litani River Basin include:

- Flow in the Litani River and its tributaries: if streamflow is to be diverted and treated, and understanding of seasonal variability in flow rates is required. Additionally, if a wetland is to be sited adjacent to the Litani River or one of its tributaries, a basic understanding of flood hydraulics and likelihood and timing of floodwaters reaching the wetland must be gained. Currently, well there are several stream gauges in the basin, but only the gage on the Litani River at Joub Jannine provides reliable data over a meaningful time period.

- Rainfall data in the Litani River Basin: a key part of a wetland water balance, rainfall will supplement inflows to the wetland and must be understood especially if heavy rains are expected that could overwhelm the flow capacity of the wetland itself. Limited rainfall data is available for the Bekaa Valley and only for some years since 2001 (LRBMS 2012a)

- Evaporation data in the Litani River Basin: estimates of potential evaporation, combined with site-specific soil infiltration data determine the minimum amount of water that must be fed to a wetland to sustain it. Inflows must exceed losses due to evapotranspiration and infiltration or the wetland will go dry, particularly in summer when evapotranspiration rates are highest. Estimates of reference evapotranspiration (ET0) exist for the Bekaa Valley (LRBMS 2011b).

- Site-specific infiltration estimate: not generally available from existing data – this must be determined for a specific proposed wetland site.

- Water quality data: an understanding of water quality at various locations in the Litani River and its tributaries as well as any other point sources of contaminated discharges will help determine a preferred treatment wetland site and will be required to perform estimates of expected treatment performance. Concentrations of certain pollutants will help guide selection of wetland components and layouts to optimize for their removal. The LRA, LRBMS, and other agencies and projects have collected and analyzed water quality samples since 1999 and the basin at various key locations. A compendium of these water quality samples between has been put together by LRBMS (2012b).

- Topography: to develop a grading plan for the site, the existing site elevations must be well known. Only limited survey data is currently available in the Litani River Basin from a river cross-section survey performed by LRBMS for the purposes of the hydraulic modeling (LRBMS 2010).

2. TREATMENT WETLANDS OVERVIEW

2.1. HISTORY

Natural ecosystem processes such as those found in wetlands can be engineered into constructed systems to provide alternatives to conventional water and wastewater treatment. Wetlands, both natural and constructed, have demonstrated effective treatment of many different types of water-borne pollutants. Wetland systems offer numerous benefits, especially in this age of concern about wetland losses and the focus on natural and open space

While vegetated aquatic systems have been used for water treatment for at least 100 years worldwide, the feasibility and technology of using wetlands for water treatment have been heavily investigated since the 1950s when researchers first observed removal of trace organics and BOD in laboratory-constructed wetlands. Since then, many scientists and engineers in the United States and abroad have conducted further studies of treatment potential in both constructed and natural systems (Kadlec and Wallace 2009). Designs range from large open-water areas fringed with cattails and bulrushes, to shallow water ponds completely covered with sedges and rushes, to natural forested wetlands. However, because of the variety of wetland types—each with differing hydrology, vegetation, and substrate—the observed treatment efficiency can vary between systems (Kadlec and Wallace 2009).

In general, wetland water treatment systems have been found to lower BOD, total suspended solids (TSS), and total nitrogen concentrations by up to 80-90 percent. Removal efficiencies for total phosphorus, metals, and organic compounds vary widely, typically ranging from 20 to 90 percent. Removal of pollutants in treatment wetlands is limited by the form and concentration of the constituents, water flow rates and wetland size, the presence of oxygen, substrate type, and the entire chemical makeup of the water to be treated (Kadlec and Wallace 2009).

Treatment wetland systems treat a wide array of contaminated waters. Common system types range from waters with consistent and predictable pollutant loads such as wastewater from industrial or agricultural production processes and municipal wastewater treatment plants to systems with unpredictable pollutant loads and varying hydrologies such as stormwater and urban runoff. This variety is a testament to the ability of wetland ecosystems to handle and process such a range of flows, chemical compounds, and pollutant loads.

2.2. ANCILLARY BENEFITS

Treatment wetlands' true value lies not only in the water treatment functions they can provide, but in the multitude of their other benefits that more traditional water treatment processes lack. Numerous facilities have been in operation in the United States for decades that demonstrate effective water treatment while at the same time providing functions and values similar to those provided by natural wetlands such as educational opportunities, wildlife habitat, and public opportunities for recreation. Litani River Basin suffers from a lack of local operations and maintenance (O&M) funding for water treatment facilities; there are at least three wastewater treatment plants either built or under construction in the Bekaa Valley that are not operating or are experiencing significant construction delays due to lack of funding. Investments in conventional wastewater treatment infrastructure have yet to have a significant impact on water quality in the basin and therefore effective non-traditional approaches to water treatment that offer greatly reduced O&M costs and complexity are an attractive solution. Treatment wetlands offer this potential. Their applicability is broad; successful treatment wetland systems exist for single-family homes up through thousands of hectares for large-scale storm water runoff treatment. They successfully remove contaminants as diverse as organic material, nutrients, heavy metals, synthetic chemicals, sediments, and more. While they have been successfully implemented even in harsh northern climates they are particularly well suited for the Mediterranean climate characterizing Lebanon. In the Bekaa Valley, where pollution concerns are highest in summer months, high temperatures promote elevated rates of microbial activity that are the heart of many of the treatment processes in wetland systems.

2.3. TYPES OF SYSTEMS

Modern treatment wetland systems span a range of technologies from systems that mimic natural wetlands in their appearance and function to more highly engineered systems that distill the key physical, chemical, and microbial processes found in wetland environments into a "black box" reactor. In between, there are treatment wetland systems based on hydroponically growing wetland vegetation in a media bed such as sand or gravel.

- Free water surface wetlands (FWS): these systems mimic a natural marsh ecosystem and often consist of shallow vegetated areas mixed with deeper open water areas that may or may not be vegetated with submerged plant species. These systems work well in almost all climates save the most extremely cold and are comparatively inexpensive to construct and operate relative to other treatment wetland types. While their treatment efficiency depends greatly on their design, they can provide very efficient treatment if properly designed to prevent short-circuiting of flow through the system.

- Horizontal subsurface flow wetlands (HSSF): these systems are composed of a gravel, sand, or other similar media bed with wetland vegetation rooting (ideally) through the full depth of the bed, which is commonly approximately 1 m deep. Flow is uniformly introduced at one end and removed at the other. These systems are operated with flow completely below the surface of the media. They are typically more expensive to construct and operate than FWS systems of the same size and unless constructed with highly specialized media for a particular pollutant often do not offer measurably greater removal efficiencies for most pollutants than do FWS systems. Clogging of the media bed can be a significant operations problem if the system is overloaded relative to its hydraulic and organic matter assimilative capacity; mineral sediments can also accumulate in the media bed. Due to lack of standing water they offer advantages of preventing wildlife contact with toxic wastewater streams and do not produce mosquito habitat.
- Vertical subsurface flow wetlands (VF): these systems are similar to HSSF wetlands but flow either vertically upward or downward with the latter often in a pulsed-flow arrangement. These offer many of the same advantages and disadvantages of HSSF systems but the pulsed downflow variety can often produce greater removal rates for pollutants requiring oxygen for removal as they provide a freshly oxygenized media bed between pulses of wastewater. These systems can suffer from the same clogging problems as HSSF wetlands.

3. LITANI RIVER BASIN PILOT WETLANDS SITE AND TYPE SELECTION

Treatment wetlands' broad applicability to pollutant types, climate conditions and other physical site characteristics means that these systems could be successfully implemented at virtually any agricultural, industrial, or urban site where wastewater could be feasibly directed into a wetland basin. However, social, political, and economic considerations substantially reduce the available sites for construction of a treatment wetland system under this USAID-funded LRBMS program. Key driving factors for siting a treatment wetland include the following:

- Land availability and ownership: the Bekaa Valley is a fertile agricultural region and therefore developable land is not inexpensive. Additionally, few lands are owned by governmental agencies or are in the public trust. To avoid the expense of purchasing land at market value, a site on publicly available lands or a partnership with a private polluter willing to install a wetland treatment system is preferable.

- Access to polluted water: the more difficult it is to convey water from the source to a wetland basin (for example, river diversion, pumping, access to existing wastewater piping infrastructure, etc.) the more costly the treatment wetland is to implement.

- Public accessibility: a goal of this project is to educate visitors to and residents of the Bekaa Valley about the serious water quality issues facing the valley, historical wetland habitats that existed, and how treatment wetlands can be part of water management solutions for the country of Lebanon. A site that is easily accessible to public visitors will help facilitate this goal.

In addition, because of the existing examples of wastewater treatment and other infrastructure constructed in the Bekaa Valley that are currently not operated due to lack of local funding, it is acknowledged that there exists an almost complete lack of local funding or staffing to operate and maintain any treatment wetland built in the valley. Therefore, any constructed treatment wetland that is part of the LRBMS must be designed so as to require the absolute bare minimum of O&M to operate effectively. This necessitates planning for the simplest system possible.

As mentioned above, FWS treatment wetlands, if properly designed to avoid short-circuiting and maximize the physical, chemical, and microbial processes for removal of the pollutants of concern, can perform as well or better than any more highly engineered, media bed-based treatment wetland system, particularly those that require careful operations and maintenance to avoid clogging. We therefore strongly recommend and have only evaluated FWS wetlands as part of this feasibility study and for this pilot project.

4. PILOT WETLAND FEASIBILITY ANALYSIS

A primary goal of the NewFields staff trip to Lebanon in January 2012 (further described in Appendix A) was reconnaissance of the Bekaa Valley to identify potential sites to be evaluated as part of this Feasibility Report. Based on conversations with IRG and LRA staff, several potential sites were identified and visited during the course of the trip. For each site, a preliminary concept plan for treatment wetlands has been prepared along with a summary of opportunities and constraints for development.

Based on evaluations by NewFields and discussions with IRG and LRA staff, a preferred site has been chosen and justification for the selection is included in this report.

The core of this report is a set of preliminary conceptual designs for implementation of treatment wetlands at four different sites within the Bekaa Valley. These designs are intended for evaluation of feasibility and selection of a preferred site for a LRBMS-funded pilot treatment wetlands project to be constructed in 2012. The selected site will be further developed and refined into a conceptual and then a final design package. These preliminary designs and their cost estimates are based on professional judgment and were guided by limited available data and assumptions obtained through interviews with IRG, LRA, and in the case of private facilities, local facility staff.

The feasibility for treatment wetland implementation has been based on availability of water suitable for treatment by wetlands, available land to treat that water, the engineering feasibility of accessing that water, and other factors that impact the cost of implementation. It is assumed that the available budget for treatment wetlands construction is approximately US$300,000 and that this constrains the possible size of the treatment wetland constructed by this project.

An overview map of the Litani River Basin with the four evaluated sites is shown in Figure 1.

4.1. SITE 1: JOUB JANNINE

4.1.1.1. OVERVIEW

Near the city of Joub Jannine, approximately 7 km northeast of Qaraoun Lake, the Litani River flows through a parcel of land owned by the LRA of approximately 100 hectares(Figure 1). This parcel of land is mostly vacant but does contain a recently constructed Litani River management center funded by the European Union's Improvement of Irrigation Water Management in Lebanon and Jordan program. Additionally, a recently constructed wastewater treatment plant serving Joub Jannine and nearby communities is located at the upstream corner of the parcel. Both the management center and wastewater treatment plant are currently not in service due to lack of operational funding for both. Because this site sits almost immediately upstream of Qaraoun Lake, is large, publicly owned, and not in agricultural production, it presents unique potential for siting a treatment wetland. Qaraoun Lake suffers from water quality problems and furthermore feeds Canal 900, the Bekaa Valley's primary irrigation infrastructure, and any water quality improvement of the Litani River in this area would have benefits extending to those water bodies as well.

4.1.1.2. WATER QUALITY SUMMARY

NewFields has developed a geographic information system (GIS) that contains all available water quality sample data from the Bekaa Valley between 1999 and 2011 obtained from LRBMS (2012b). A summary of median values of pollutants of interest for samples collected in the Litani River near the Joub Jannine bridge crossing is presented in Figure 2. With the exception of BOD (slightly higher during the wet season) and nitrate (similar median concentrations in both seasons) most pollutants of concern are present in substantially higher concentrations in the dry season versus the wet season. This indicates that that the Litani River near Joub Jannine likely receives domestic sewage and agricultural drainage containing nutrients and pathogens during the dry season and similar pollutants diluted by storm events during the wet season. It is important to note that the samples that make up

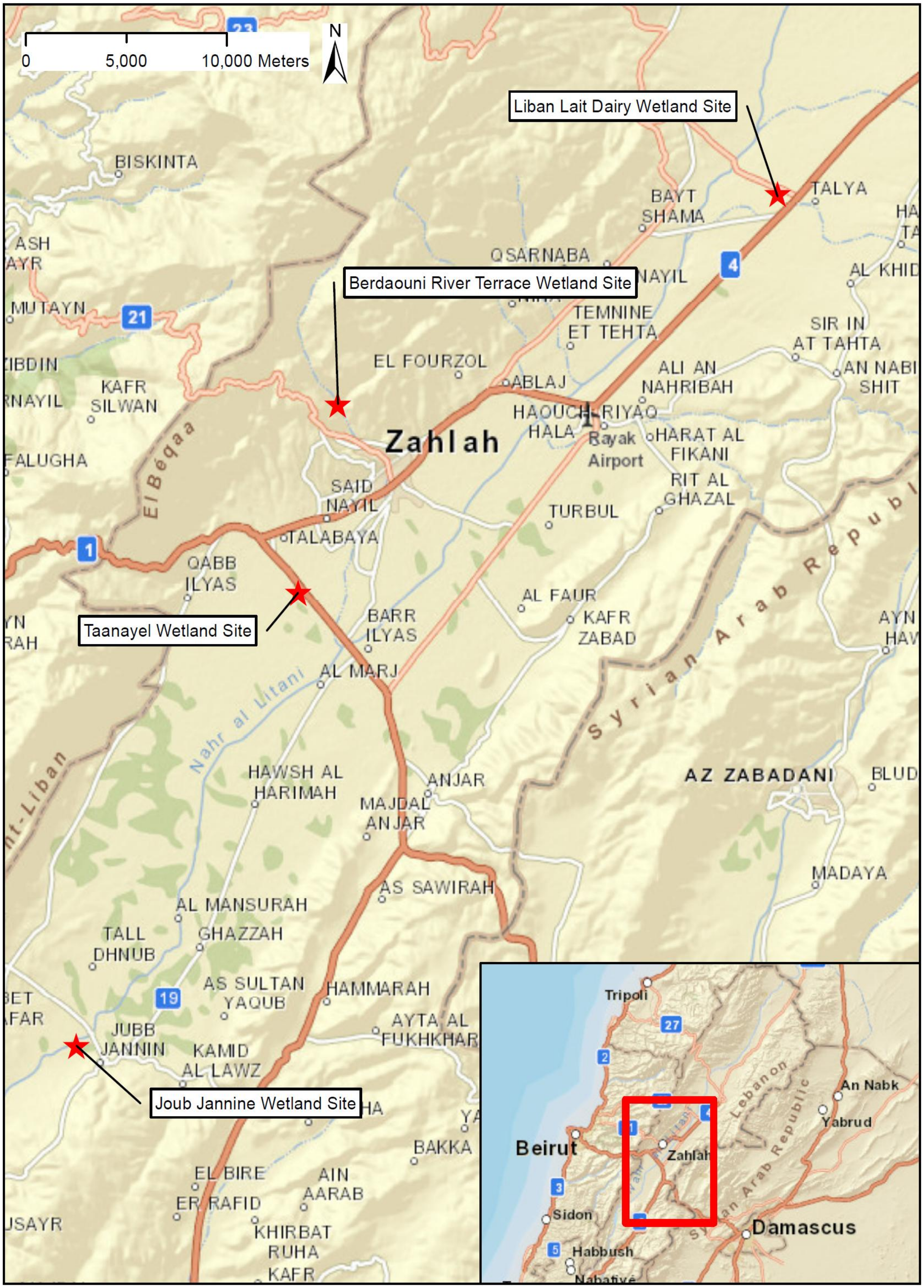
0
5,000
10,000 Meters
N
Liban Lait Dairy Wetland Site
Berdaouni River Terrace Wetland Site
Taanayel Wetland Site
Joub Jannine Wetland Site
Zahlah
BISKINTA
BAYT SHAMA
TALYA
QSARNABA
AL KHID
MUTAYN
TEMNINE ET TEHTA
SIR IN AT TAHTA
EL FOURZOL
ABLAJ
ALI AN NAHRIBAH
AN NABI SHIT
KAFR SILWAN
HAOUCH HALA
RIYAQ
Rayak Airport
HARAT AL FIKANI
FALUGHA
El Béqaa
SAID NAYIL
RIT AL GHAZAL
TURBUL
TALABAYA
QABB ILYAS
AL FAUR
KAFR ZABAD
BARR ILYAS
AL MARJ
Nahr al Litani
Syrian Arab Republic
HAWSH AL HARIMAH
ANJAR
MAJDAL ANJAR
AZ ZABADANI
BLUD
MADAYA
AS SAWIRAH
AL MANSURAH
TALL DHNUB
GHAZZAH
AS SULTAN YAQUB
HAMMARAH
AYTA AL FUKHKHAR
JUBB JANNIN
KAMID AL LAWZ
BAKKA
EL BIRE
ER RAFID
AIN AARAB
KHIRBAT RUHA
KAFR
Tripoli
Beirut
Zahlah
Sidon
Habbush
Lebanon
Syrian Arab Republic
An Nabk
Yabrud
Damascus

Figure 1: Bekaa Valley Location Map and Four Wetland Sites Evaluated

this data set are mostly from prior to the completion of the wastewater treatment plant and may or may not have been collected downstream of its outfall. Therefore, this data set may or may not accurately represent current water quality conditions in the Litani River at the site of the proposed wetland.

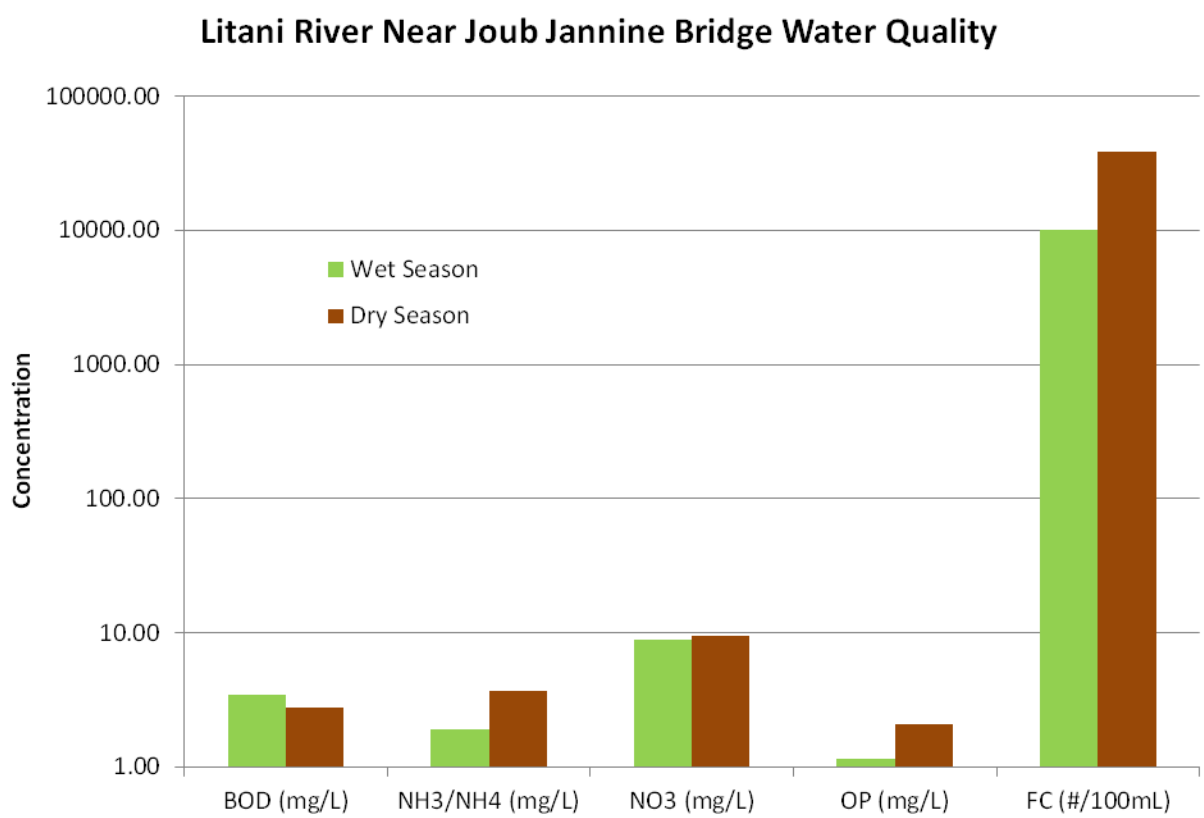

Figure 2: Summary of Water Quality Litani River Near Joub Jannine Bridge

Note logarithmic scale; NH3/NH4 = Ammonia, NO3 = nitrate, OP = orthophosphate, FC = fecal coliforms

4.1.1.3. HYDROLOGY SUMMARY

The most reliable stream gauging station in the Litani River Basin is located on the Litani River at the Joub Jannine bridge, which is located immediately upstream of the LRA property. Figure 3 shows the average observed flow rate between the water years 1999 to 2009 distributed by month. The stream flow pattern typifies the Mediterranean climate; very high flows are observed January through April (peaking with an average flow in February of 24.1 m^3 /s) with almost no flow between July and October (with the lowest average flow in August of 0.2 m^3/s).

From a treatment wetland implementation perspective, the Litani River provides ample flow during winter through late spring to support vegetation, but June through October may present a challenge if river flows are too low to pump or divert. Typical wetland vegetation is resilient and can withstand weeks of dry conditions without serious damage, but a full summer without available water would support only a seasonal wetland that would not provide optimal treatment performance. While the average flow distribution shows flow in all months, streamflow data from the period 1999-2009 shows several years with a recorded flow of zero between June and October. It is unclear whether this truly represents a dry riverbed or a very low flow below the threshold measurable at the gage.
However, the Canal 900 irrigation network supplies water to the LRA parcel, and we assume for this feasibility analysis that if enough flow is not available in the Litani River itself during summer months that Canal 900 water may be used to supplement the wetland's flow. Also, the completion of the wastewater treatment plant nearby occurred after the latest available stream gage data (and it is downstream of the gage) so the wastewater treatment plant outfall may provide additional flows not captured in the available gage data.

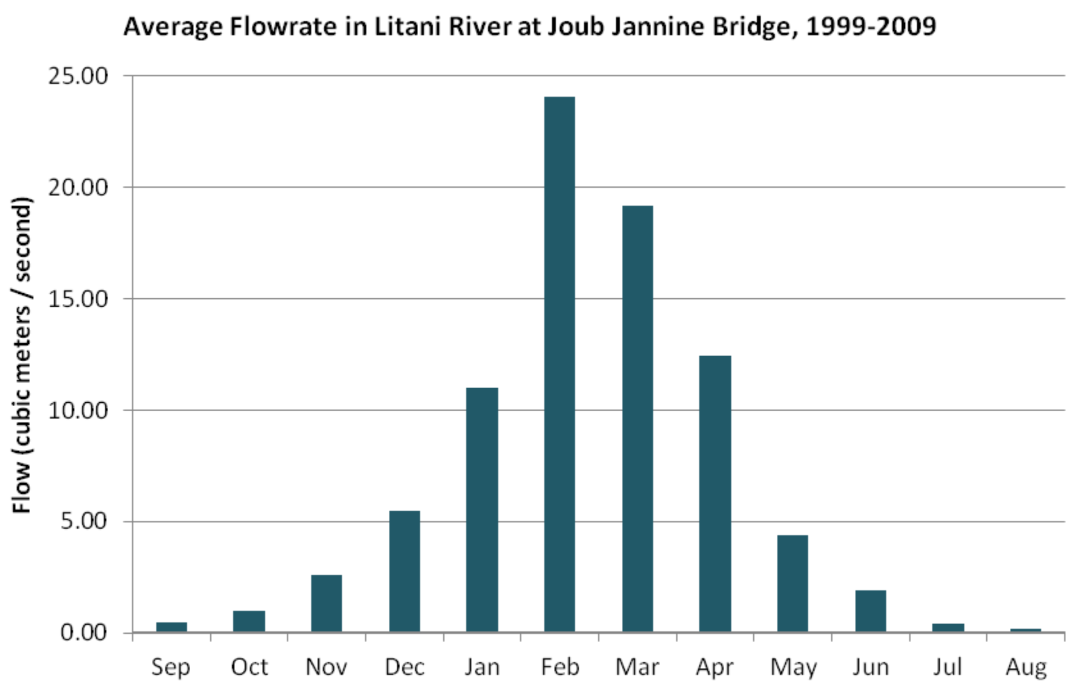

Figure 3: Average Flow in the Litani River at Joub Jannine

4.1.1.4. TREATMENT WETLAND OPPORTUNITIES AND CONSTRAINTS

Because it is publicly owned, flat, adjacent to the Litani River, and very large, the LRA parcel near Joub Jannine is an ideal site for a treatment wetland. Additionally, given that the new wastewater treatment plant nearby is currently not operating due to lack of operating funds and therefore discharges untreated wastewater at the upstream end of the site, a treatment wetland presents an opportunity to improve water quality without the need for an expensive operating budget. The proximity of the LRA water management center, which provides a parking lot and easy walking access to the river as well as the Aammiq wetlands (a UNESCO biosphere reserve) approximately 10 km away could enable development of a treatment wetland system at the Joub Jannine site to be part of a greater environmental education and aquatic ecosystem awareness effort in the Bekaa Valley.

As mentioned above, an important site constraint is the availability of summer flow to support wetlands but integration with the nearby wastewater treatment plant (whose collection system may not have been in place nor contributed to the available data set ending in August 2009) and Canal 900 infrastructure has potential to alleviate this problem.

Given the site's location immediately adjacent to the Litani River, a treatment wetland could be implemented on the riverbank and fed by either a pump or diverted water from the Litani River. During winter months, such a wetland might only treat a portion of the flow, but given the low river flows in summer, there is the potential for a wetland to treat most, if not all of the river's flow during the summer months. Such a system could have a significant water quality impacts downstream in Qaraoun Lake and Canal 900.

4.1.1.5. POTENTIAL TREATMENT EFFICIENCY

NewFields performed a preliminary analysis to predict treatment performance of an approximately 3.5 hectare wetland system at the Joub Jannine site treating approximately 1500 m^3/d during the summer and approximately 3000 m^3/d during the wet season. Feeding the wetland with higher flows in the winter seeks to maximize pollutant removal performance while the lower summer flow seeks to provide the minimum flow required to sustain the wetland (acknowledging the scarcity of water at the site in summer months).

Table 1 summarizes performance expectations for the proposed treatment wetland system shown in Figure 4. As noted above, the available data set may or may not accurately represent the contribution of the newly constructed wastewater treatment plant near Joub Jannine. For example, the BOD and fecal coliforms concentrations in particular for wetland influent shown in Table 1are not consistent with those expected downstream of an untreated sewage discharge. BOD removals predicted are low due to the fact that median values from the available data set are near the lower limit achievable by treatment wetlands. High removal rates for nitrogen, phosphorus, and fecal coliforms are predicted during the summer season. Nutrient removal in the wintertime is diminished because of heavier loading of the system and temperature effects on microbial activity which is a dominant removal mechanism for nitrogen in particular. However, high fecal coliform removal rates are predicted during winter operations.

Pollutant	BOD (mg/L)	NO3 (mg/L)	NH3 (mg/L)	OP (mg/L)	FC (#/100mL)
Winter Influent	3.5	9	1.9	1.1	10000
Winter Effluent	2.7	7.6	1.2	0.8	1500
Winter % Removal	23%	16%	37%	27%	85%
Summer Influent	2.8	9.6	3.7	2.1	39000
Summer Effluent	2.3	1.3	0.7	1.2	2000
Summer % Removal	18%	86%	81%	43%	95%

Table 1: Joub Jannine Wetland Performance Expectations

4.1.1.6. CONCEPT DESCRIPTION AND COST ESTIMATE

A preliminary concept for a treatment wetland system at the Joub Jannine site is shown in Figure 3. Because of the available land area and proximity to the river, there are few constraints on shape, size, and configuration of such a system. We propose a two-celled wetland complex with a larger (approximately 3.5 ha) treatment-focused cell and a smaller (approximately 1500 m^2) habitat-focused cell; however, both cells would provide both treatment and habitat functions. The cells would be adjacent to the river and reachable on foot via a path from the nearby LRA center.

The habitat-focused cell would be located strategically at a rightward bend of the river. This cell would be excavated substantially lower (as much as 2 to 3 m) below the surrounding grade to enable partial flooding during large flow events in the winter. Choosing a rightward bend for such a wetland cell ensures that the highest channel velocities during such a high flow event would be on the opposite side of the river from the cell itself, helping to minimize erosion impacts. The purpose of a "flood-able" cell is to re-create some of the natural floodplain wetlands that dominated the Bekaa Valley prior to human development. Flows from the main treatment-focused cell will cascade into the lower, habitat-focused cell and then cascade into the river during normal operation.

Because there are many options for timing and sources of water to be treated in this wetland complex, there are also many options for how to accomplish inflows to the site. These options include:

- Pumping from the river: the easiest way to access Litani River water would be to install a pump near the inflow side of the wetland. However, this option incurs the ongoing cost and maintenance of the small pump station capable of output between approximately 1500 and 3000 m^3/d. However, options exist for powering such a pump station with solar energy.

Figure 4: Conceptual Figure of Joub Jannine Wetland Park

- Gravity diversion from the river: installation of a permanent or semi-permanent dam to create enough gravity head to drive water to the wetland complex. Given that the valley slope may be as low as 0.03-0.04%, this would require a diversion to be on the order of 5 km upstream to provide enough head yet maintain a reasonable freeboard in the channel.

- Joub Jannine wastewater: tap the effluent line of the Joub Jannine wastewater treatment plant and send a portion to the wetland site. An advantage of this option is that the treatment plant is very closely located and there may be sufficient existing head to convey this water to the site. However, raw, untreated sewage may prove difficult to treat in the wetland system required to operate with little or no regular maintenance.

- Connection to Canal 900: tap into existing piping on the northwest side of the Litani River providing Canal 900 irrigation water to nearby croplands. This may be the best option for supplemental summer flows if in-channel Litani River flows are not sufficient to sustain the wetlands.

Given this site's proximity equipped to the Aammiq Wetlands and easy access to facilities and parking at the LRA center, we envision this site set up for visitation with walking paths and environmental education exhibits and signage. This "wetland park" concept has the potential to provide benefits far beyond water quality improvement in that it can educate visitors about the importance of wetland habitats, the water quality issues in the Bekaa Valley, and the efficacy of treatment wetlands to improve water quality improvements in a sustainable, ecological manner.

Table 2 presents a planning-level cost estimate for this wetland park concept. This cost estimate can be considered to have an approximate accuracy of +100/-50% which is consistent with the level of preliminary development of this idea. Given the many potential options for sourcing water for these wetlands, we have assumed a Litani River pump station and a connection to the Canal 900 infrastructure as representative for the range of available options.

Construction Item	Units	Unit Cost (US$)	Amount	Cost
Earthmoving	m^3	$ 6.75	15000	$ 101,250
Berms	m	$ 20.00	3600	$ 72,000
Planting	ha	$ 15,000.00	2.7	$ 40,500
Piping, Pump, and Structures	Lump Sum	NA	NA	$ 50,000
Trails, Signage, Misc	Lump Sum	NA	NA	$ 20,000
Contingency (30%)	Lump Sum	NA	NA	$ 79,250
Total				$ 363,000

Table 2: Preliminary Cost Estimate, Joub Jannine Wetland Park

4.2. SITE 2: TAANAYEL DAIRY FARM

4.2.1.1. OVERVIEW

The Tannayel dairy farm is located between Zahle and Qoub Elias in the Bekaa Valley near the Berdaouni and Chtaura Rivers (Figure 1). Originally a Jesuit Catholic monastery with vineyards and dairy production, it is now in private ownership by the nongovernmental organization (NGO) ArcenCiel and managed as a for-profit dairy farm and vineyards with an eco-lodge on site. The farm draws water from the Chtaura River and stores it in a lake on the property for irrigation use. This water contains the typical types of pollution found in virtually all tributaries of the Litani River – organic material, pathogens, and nutrients from untreated sewage and nutrients from agricultural drainage. A portion of the lake on the property could be converted to wetlands for the purpose of treating irrigation inflows, thereby improving the quality of the water used for irrigation. Additionally, the farm produces approximately 22 m^3/d of dairy wastewater that is currently disposed of via either a septic system for direct discharge to Litani River tributaries. An additional treatment wetland could be constructed on site to treat these dairy wastes before discharge.

4.2.1.2. WATER QUALITY SUMMARY

A summary of median values of pollutants of interest for samples collected in the Chtaura River near the Tannayel farm diversion channel is presented in Figure 5. Some general trends are evident. Pollutants typically derived from sewage are higher in the dry season when storm water dilution is not occurring (i.e., coliforms and ammonia; BOD is an exception to this trend). Also, pollutants typically derived from agricultural storm water runoff are higher in the wet season when storms are occurring (fertilizer-derived nutrients such as nitrate and orthophosphate).

These water quality data indicate a stream heavily impacted by domestic sewage discharges from nearby cities such as Jdita as well as runoff and drainage from heavily-fertilized agricultural fields. While the observed concentrations of BOD and nutrients do not pose a problem for use as an irrigation supply source, the observed levels of pathogens do.

The Tannayel Dairy Farm also generates wastewater from its dairy operations. While no data are available to indicate the levels of pollution present in these discharges, dairy wastewater typically contains very high levels of BOD, ammonia, phosphorus, and TSS.

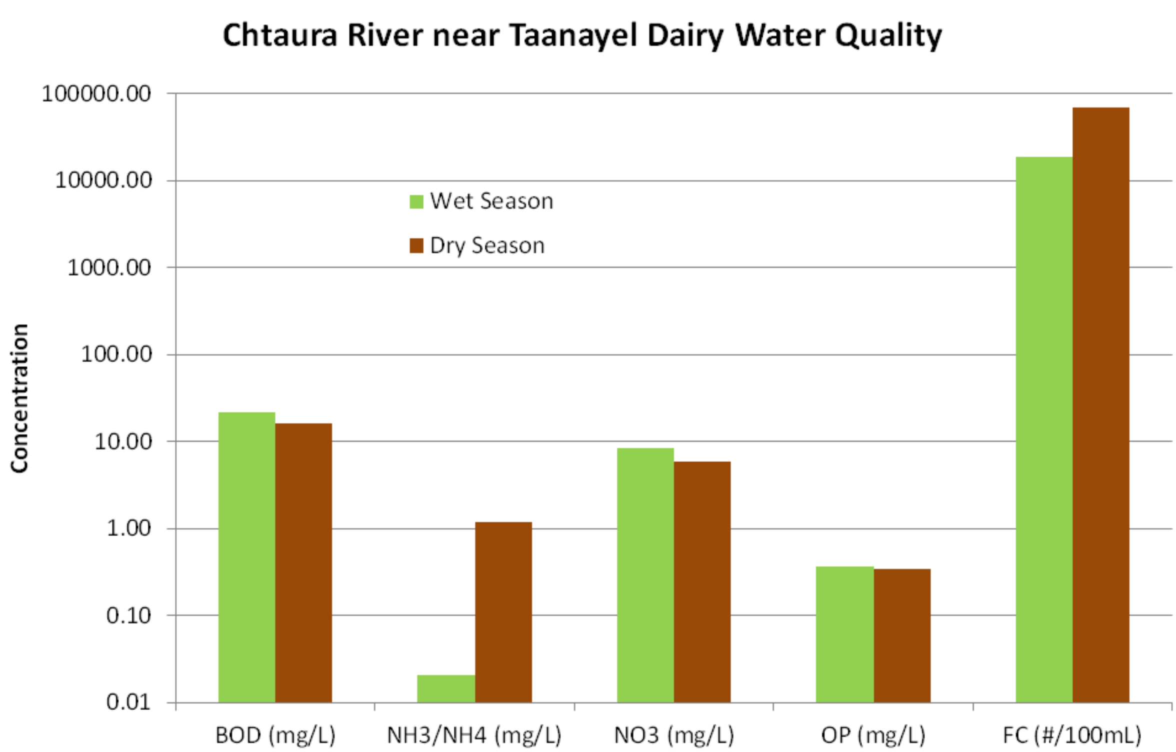

Figure 5: Water Quality Summary near Taanayel Dairy. ***Note logarithmic scale.***

4.2.1.3. HYDROLOGY SUMMARY

The Tannayel dairy farm currently diverts approximately 1,000,000 m^3 per year of water from the Chtaura River between approximately October through July. This corresponds to approximately 3300 m^3/d flow rate, although flows are likely higher between December-May during rainfall and snow melt periods and lower in October-November and June-July. The dairy facilities produce approximately 22 m^3/d of wastewater effluent from 100 cows. However, the dairy plans to eventually expand to 300 to 400 cows.

4.2.1.4. TREATMENT WETLAND OPPORTUNITIES AND CONSTRAINTS

4.2.1.4.1. DIVERTED RIVER WATER FOR IRRIGATION

Tannayel Dairy Farm's usage of the diverted water from the Chtaura River as irrigation for crops and for recreation in the on-site lake mean that the primary pollutants of concern are coliform bacteria (and likely also present but un-analyzed pathogens such as other bacteria and viruses). Secondary pollutants of concern would be nutrients such as nitrate in orthophosphate, which can cause algae blooms in the lake.

Treatment wetlands are known to remove all these pollutants of concern, making them an ideal technology for treating incoming diverted river water at this site. Rather than take agricultural land out of production, a portion of the on-site lake could be converted to a wetland treatment system, providing water quality benefits for the rest of the lake as well as enhancing the lake's ecological diversity and habitat value.

4.2.1.4.2. DAIRY FACILITY WASTEWATER

The dairy facility wastewater effluent contains very high levels of organic material, nutrients, and suspended solids. Currently, the facility discharges its dairy wastewater to a septic system, but this system likely leaches these contaminants, particularly nutrients, into local groundwater and Litani River tributaries. Properly sized and designed treatment wetland systems are well known to provide very high levels of removal for dairy wastewater contaminants (Kadlec and Wallace 2009). However, such a system could require up to one or more hectares for the current facility with 100 cows or four or more hectares if expansion to 300 to 400 cows occurs.

4.2.1.5. POTENTIAL TREATMENT EFFICIENCY

NewFields performed a preliminary analysis to predict treatment performance of wetland systems for both diverted river water and dairy wastewater at the Tannayel Dairy Farm. We made the following simplifying assumptions:

Diverted River Water

- treated in 5000 m^2 "corner" portion of the on-site lake
- 5000 m^3/d winter inflow rate, 500 m^3/d summer recirculation rate from lake water
- lake water quality in summer matches median observed winter Chtaura River water quality

Dairy Wastewater

- treated in a wetland system sized 100 m^2 per cow
- 22 m^3/d year-round flow rate
- Typical dairy water quality: 9000 mg/L BOD; 1000 mg/L TSS; 50 mg/L ammonia; 50,000 #/100mL fecal coliforms (Kadlec and Wallace 2009)

Tables 3 and 4 summarize performance expectations for the two proposed treatment wetland systems at the Tannayel Dairy Farm. Because of its small size relative to the flow treated, the lake "corner" wetland does not provide effective winter removal for most contaminants. However, fecal coliforms are reduced by 20%. During the summer months, when there is no flow in the Chtaura River to divert, we assume installation of a small recirculation pump to feed lake water to the treatment wetland to both sustain wetland vegetation and provide lake water treatment. At this lower flow rate of 500 m^3/d, the wetland is no longer overloaded and provides a much greater degree of pollutant removal.

The proposed dairy wastewater effluent treatment wetland system performance summarized in Table 4 shows very high levels of treatment for the pollutants considered. This is due to the significantly smaller flow rate of wastewater and the larger size of the wetland (assumed 100 m^2 per cow or one hectare currently). BOD and fecal coliforms removals are largely independent of temperature and therefore year-round performance is the same. TSS outflow concentrations in treatment wetlands are often controlled both by the removal of the wetland and internal production due to algae growth. In the summer, when temperatures are higher and there are more hours of sunlight per day, algae production is increased and therefore we predict higher outflow concentrations (and therefore lower removal rates) of TSS. Due to higher temperatures and associated greater microbial activity in summer, ammonia removal is highest during that period. Note that ammonia is removed by first conversion to nitrate and second by removal as gaseous nitrogen; therefore, there is an associated nitrate production with removal of ammonia and while nitrate is generally not present in dairy wastewater effluent, it will be present in wetland effluent as noted in Table 4.

Pollutant	BOD (mg/L)	NO3 (mg/L)	OP (mg/L)	FC (#/100mL)
Influent	21	8.4	0.4	43000
Winter Effluent	19	8.2	0.4	34500
Winter % Removal	10%	2%	0%	20%
Summer Effluent	12	2.3	0.3	7800
Summer % Removal	43%	73%	25%	82%

Table 3: Taanayel Lake Wetland Performance Expectations

Pollutant	BOD (mg/L)	TSS (mg/L)	NH3 (mg/L)	FC (#/100mL)
Influent	9000	1000	50	50000
Winter Effluent	63	73	<2*	42
Winter % Removal	99%	93%	96%	100%
Summer Effluent	63	257	<1	42
Summer % Removal	99%	74%	99%	100%

**during winter months we predict an additional wetland nitrate effluent concentration of approximately 2 mg/L*

Table 4: Taanayel Dairy Wastewater Wetland Performance Expectations

4.2.1.6. CONCEPT DESCRIPTION AND COST ESTIMATE

Figure 6 depicts the concept for treatment of Chtaura River diversion at a lake "corner" wetland for the Tannayel Dairy Farm. Currently, the diversion from the river flows through a simple concrete box culvert and into the lake. This would be modified to accommodate the new elevation of the lake corner where the wetland would be constructed. While the bathymetry of the lake is unknown, it is presumed that the lake bottom in the corner would need to be raised approximately 2 m (based on available photographs of the lake during high/low water levels). Raising the bottom of the lake (to facilitate the shallow depths required for wetland vegetation) would likely be the greatest single cost in construction of this wetland. A new berm extension would close off the corner from the existing lake and contain it outflow structure to drain the wetland into the lake.

A planning-level cost estimate for this treatment wetland is presented in Table 5. This cost estimate can be considered to have an approximate accuracy of +100/-50% which is consistent with the level of preliminary development of this treatment wetland concept.

Figure 7 depicts the dairy wastewater treatment wetland for the Tannayel Dairy Farm. Dairy wastewater would be conveyed away from the milking facilities and holding pens and sent through a wetland treatment system consisting of a small settling lagoon and one or more wetland treatment cells. The effluent from the wetlands, with greatly reduced or nearly

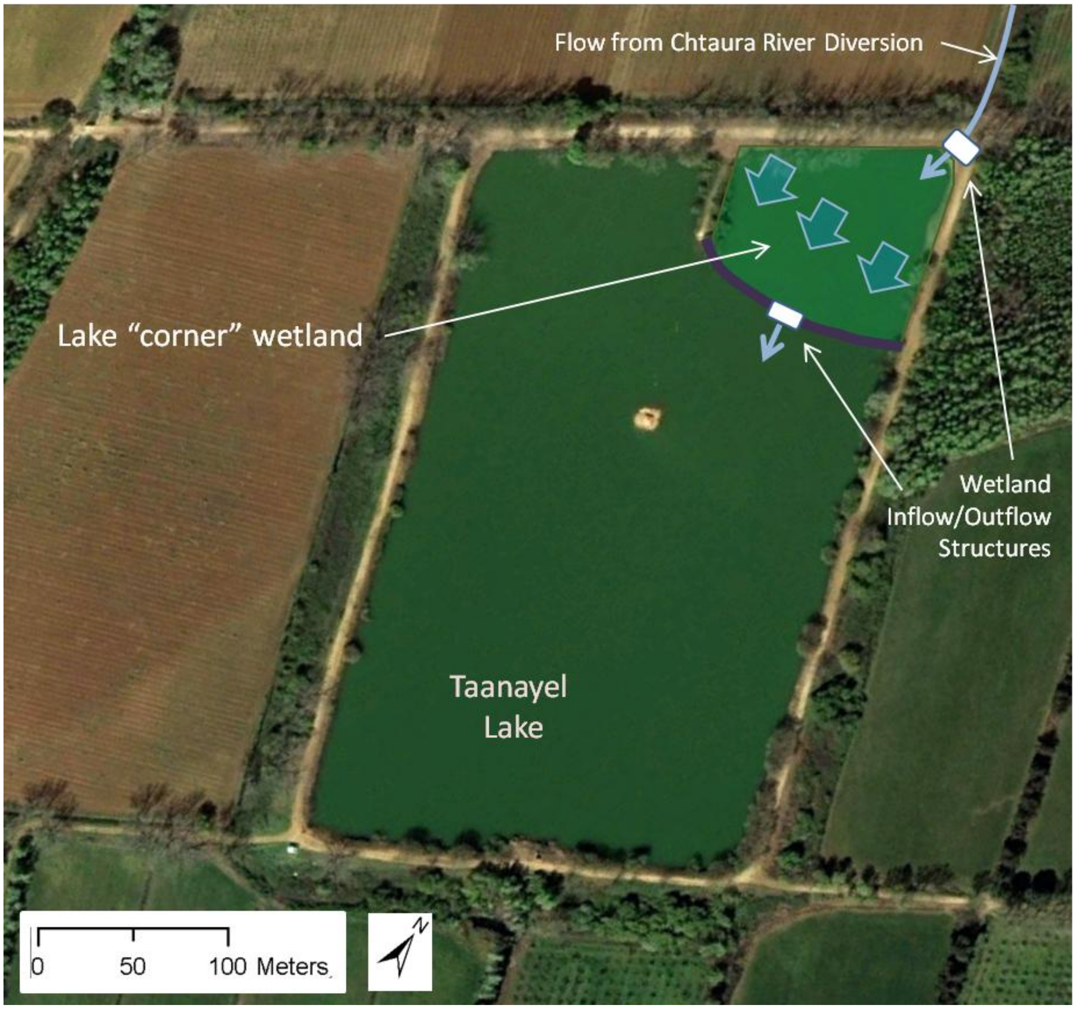

Figure 6: Conceptual Figure of Taanayel Lake Treatment Wetland

Construction Item	Units	Unit Cost (US$)	Amount	Cost
Soil Import	m^3	$ 20.00	10000	$ 200,000
Earthmoving	m^3	$ 8.50	11000	$ 74,250
Planting	ha	$ 15,000	0.5	$ 7,500
Piping and Structures	Lump Sum	NA	NA	$ 10,000
Contingency (30%)	Lump Sum	NA	NA	$ 87,500
Total				$ 379,000

Table 5: Preliminary Cost Estimate for Taanayel Lake Treatment Wetland

eliminated pathogens, bacteria, organic material, etc. could then be used as an irrigation supply source for nearby fields. This may involve the addition of a small holding pond or similar facility to enable irrigation reuse of this water. Such reuse is also subject to salinity requirements of the crops grown. Dairy wastewater can contain elevated levels of salts that may become concentrated due to evaporation in the wetlands.

Figure 7 depicts a 1 hectare footprint for a wetland system with an expansion area shown to enlarge the system for treatment of wastewater generated from up to 400 cows if the Tannayel dairy farm expands as planned.

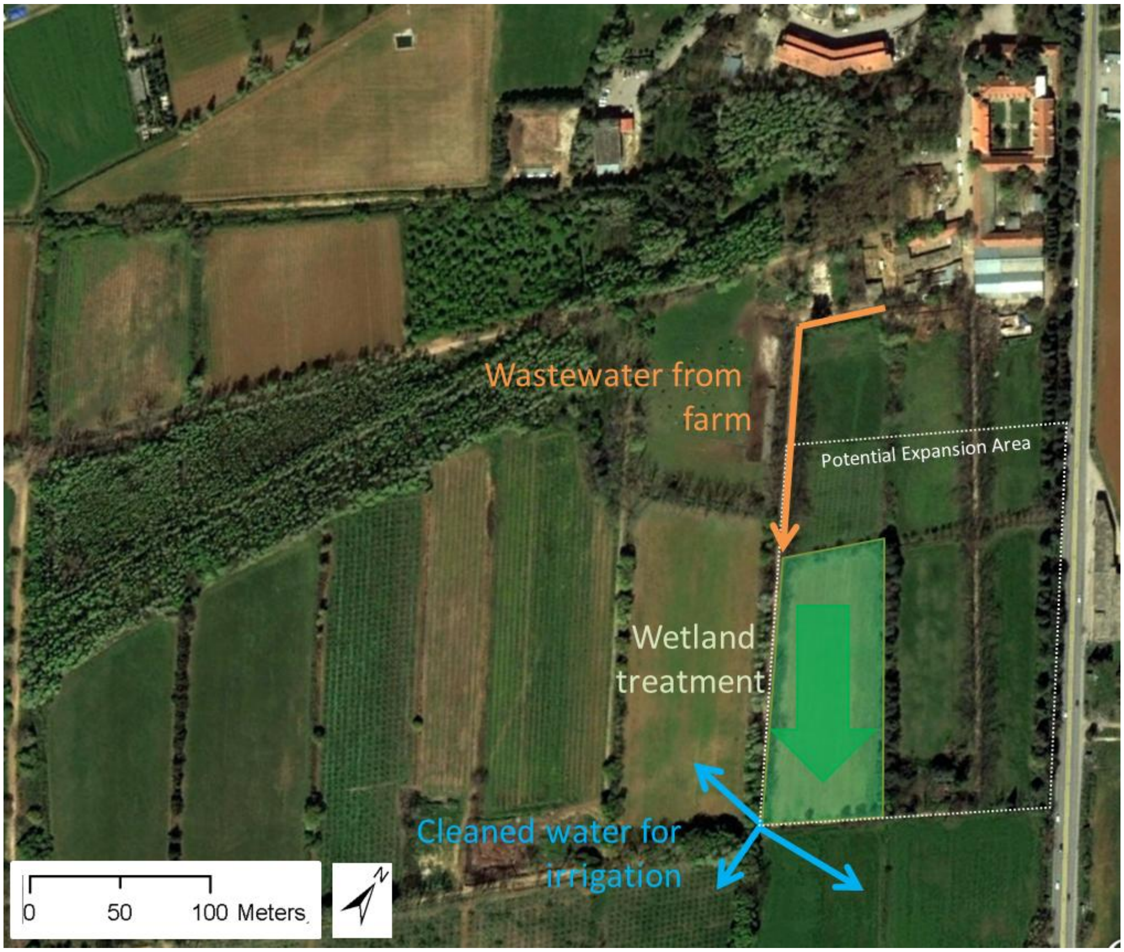

Figure 7: Conceptual Figure of Taanayel Dairy Wastewater Treatment Wetland

A planning-level cost estimate for this treatment wetland is presented in Table 6. This cost estimate can be considered to have an approximate accuracy of +100/-50% which is consistent with the level of preliminary development of this treatment wetland concept.

Construction Item	Units	Unit Cost (US$)	Amount	Cost
Earthmoving	m^3	$ 6.75	3500	$23,500
Berms	m	$ 20.00	500	$10,000
Planting	ha	$ 15,000	1	$15,000
Piping and Structures	Lump Sum	NA	NA	$25,000
Contingency (30%)	Lump Sum	NA	NA	$22,000
Total				$96,000

Table 6: Preliminary Cost Estimate for Taanayel Lake Treatment Wetland

4.3. SITE 3: LIBAN LAIT DAIRY FARM

4.3.1.1. OVERVIEW

The Liban Lait dairy farm, Lebanon's largest, is located between Zahle and Baalbek in the middle of the Bekaa Valley (Figure 1). Like the Tannayel dairy farm, it produces wastewater from both dairy operations and livestock holding pens characterized by extremely high levels of BOD, nutrients, and pathogens. Currently, this wastewater bypasses a recently constructed lagoon system and is directly discharged into the Litani River. Similar to the Tannayel farm, a treatment wetland system could be constructed on site to treat these dairy wastes before discharge. For the purposes of this project, a pilot system is considered because the scale of the facility would necessitate a very large system to treat the entire wastewater stream and would be beyond the scope and financial resources of the LRBMS.

4.3.1.2. WATER QUALITY SUMMARY

Limited available sampling of Liban Lait effluent is available (LRBMS 2011) that indicates average discharges to the river containing approximately 9000 mg/L BOD, and 8 mg/L nitrate. For the purposes of this analysis we assume the same concentrations of ammonia, TSS, and coliforms (data not available at this time) as for the Tannayel Dairy Farm analysis above.

4.3.1.3. TREATMENT WETLAND OPPORTUNITIES AND CONSTRAINTS

Liban Lait has plenty of available land to site a treatment wetland facility large enough to handle all its wastewater (on the order of 10 to 20 ha) and therefore a wetland system is a viable option. For this analysis, we considered a treatment wetland system of approximately 2 hectares which could treat between 50 to 100 m^3 per day or 10 to 20% of the total wastewater load.

4.3.1.4. POTENTIAL TREATMENT EFFICIENCY

NewFields performed a preliminary analysis to predict treatment performance of a wetland system for dairy wastewater at the Liban Lait Dairy Farm. Table 7 summarizes performance expectations, which are similar to those predicted above for the Tannayel Dairy Farm due to similar effluent quality and ratio of wetland size to flow treated.

Pollutant	BOD (mg/L)	TSS (mg/L)	NH3 (mg/L)	NO3 (mg/L)	FC (#/100mL)
Influent	9000	1000	50	8	50000
Winter Effluent	63	73	<2	<2	42
Winter % Removal	99%	93%	96%	71%	100%
Summer Effluent	33	257	<1	<1	42
Summer % Removal	99%	74%	99%	99%	100%

Table 7: Liban Lait Dairy Wastewater Wetland Performance Expectations

4.3.1.5. CONCEPT DESCRIPTION AND COST ESTIMATE

Figure 8 depicts a proposed pilot scale treatment wetland system of approximately 2 hectares for the Liban Lait dairy wastewater. The wastewater is currently piped to the Litani River from nearby the north corner of the existing unused lagoon treatment system. The layout shown in Figure 8 proposes to use the existing pipeline to the Litani River for wetland discharge; however, if additional land nearby is available the option exists for reuse of wetland effluent to irrigation cropland or dispose of wetland effluent by land application. Such reuse of wetland effluent prevents any directly discharged to Litani River and might allow for a substantially reduced treatment wetland size and cost. This is due to the fact that the desired level of treatment for irrigation or land application reuse would be substantially less than that for protection of the Litani River aquatic ecosystem; BOD and nutrient removal would therefore be de-emphasized. The primary pollutants of concern would be pathogens and coliform bacteria in this scenario and these would be sufficiently treated in a wetland of reduced size. Additionally, a smaller wetland system would reduce evaporative losses of water that can concentrate salts in the wetland effluent. For irrigation reuse, the total dissolved solids (TDS) of the dairy wastewater could be a concern. LRBMS (2011c) reports Liban Lait effluent TDS concentrations of approximately 2400 mg/L that would likely reduce yields of typical forage crops such as alfalfa but may still be suitable for more salt-tolerant crops.

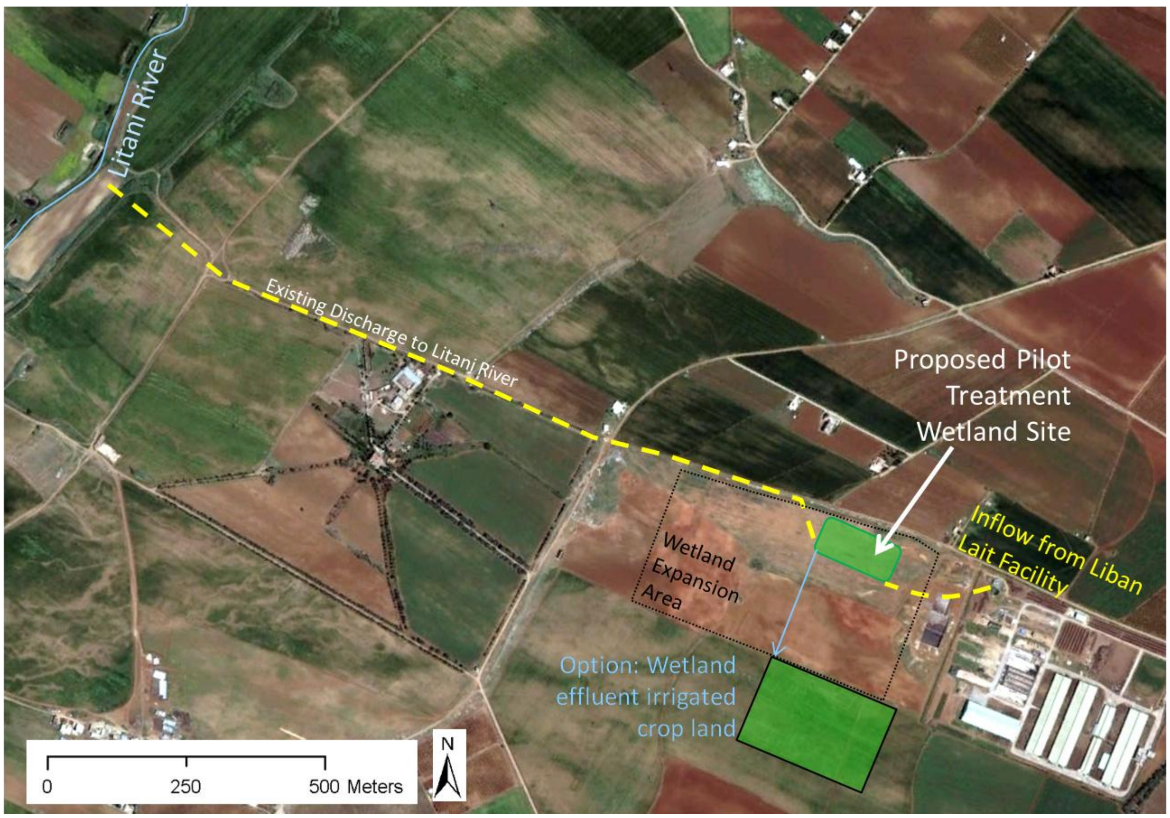

Figure 8: Conceptual Figure of Liban Lait Dairy Farm Treatment Wetland

A planning-level cost estimate for this treatment wetland (assuming Litani River discharge and excluding irrigation reuse/land application options) is presented in Table 8. This cost estimate can be considered to have an approximate accuracy of +100/-50% which is consistent with the level of preliminary development of this treatment wetland concept.

Construction Item	Units	Unit Cost (US$)	Amount	Cost
Earthmoving	m^3	$ 6.75	10000	$ 68,000
Berms	m	$ 20.00	1000	$ 20,000
Planting	ha	$ 15,000	2	$ 30,000
Piping and Structures	Lump Sum	NA	NA	$ 25,000
Contingency (30%)	Lump Sum	NA	NA	$ 43,000
Total				$ 186,000

Table 8: Preliminary Cost Estimate for Taanayel Lake Treatment Wetland

4.4. SITE 4: BERDAOUNI RIVER TERRACE WETLAND

4.4.1.1. OVERVIEW

The Berdaouni River flows from the east side of Mount Sannine and natural springs at Qaa Er Rim through a narrow canyon into the city of Zahle at the foothills of the mountain. After Zahle, it turns southwards down the Bekaa Valley before meeting the Chtaura River and immediately thereafter joining the Litani River. Directly above the center of Zahle, a series of cafés is situated along a channelized portion of the Berdaouni River canyon with outdoor seating. During the spring and summer months, when flows in the Berdaouni River are greatly reduced and dominated by untreated sewage discharges from upstream communities, the odors emanating from the river severely impact the café businesses. Several terraced areas adjacent to the river exist upstream of the cafés that are currently used for small-scale agricultural production but could be converted to treatment wetland systems with a diversions from the river. Such systems would treat a portion of the river flow during the rainy season and potentially all of the flow during the critical summer season and potentially reduce or eliminate the malodorous conditions impacting the cafés.

4.4.1.2. WATER QUALITY SUMMARY

A summary of median values of pollutants of interest for samples collected in the Berdaouni River upstream of the cafés is presented in in Figure 9. As also observed at other sites in the basin, pollutants typically derived from sewage are higher in the dry season when storm water dilution is not occurring (coliforms, ammonia, BOD). Pollutants typically derived from agricultural and urban stormwater runoff are higher in the wet season when storms are occurring (fertilizer-derived nutrients such as nitrate and orthophosphate; heavy metals). These water quality data show that the Berdaouni River is impacted by urban, agricultural, and industrial discharges (the Mimosa paper production facility is located upstream along the river).

4.4.1.3. HYDROLOGY SUMMARY

Reliable stream gage data is not available for the Berdaouni River. Therefore, for the purposes of this analysis only general assumptions about the amount of flow in wet and dry seasons can be made. However, for the purposes of developing treatment wetland concepts at the existing terraces upstream of the cafés, the available size of terraces upstream of the cafés will determine the maximum volume of water that can be feasibly treated.

4.4.1.4. TREATMENT WETLAND OPPORTUNITIES AND CONSTRAINTS

Two potential terraces (approximately 1500 and 3000 m^2 each) were identified for developing off-channel treatment wetlands along the Berdaouni River. The larger area was

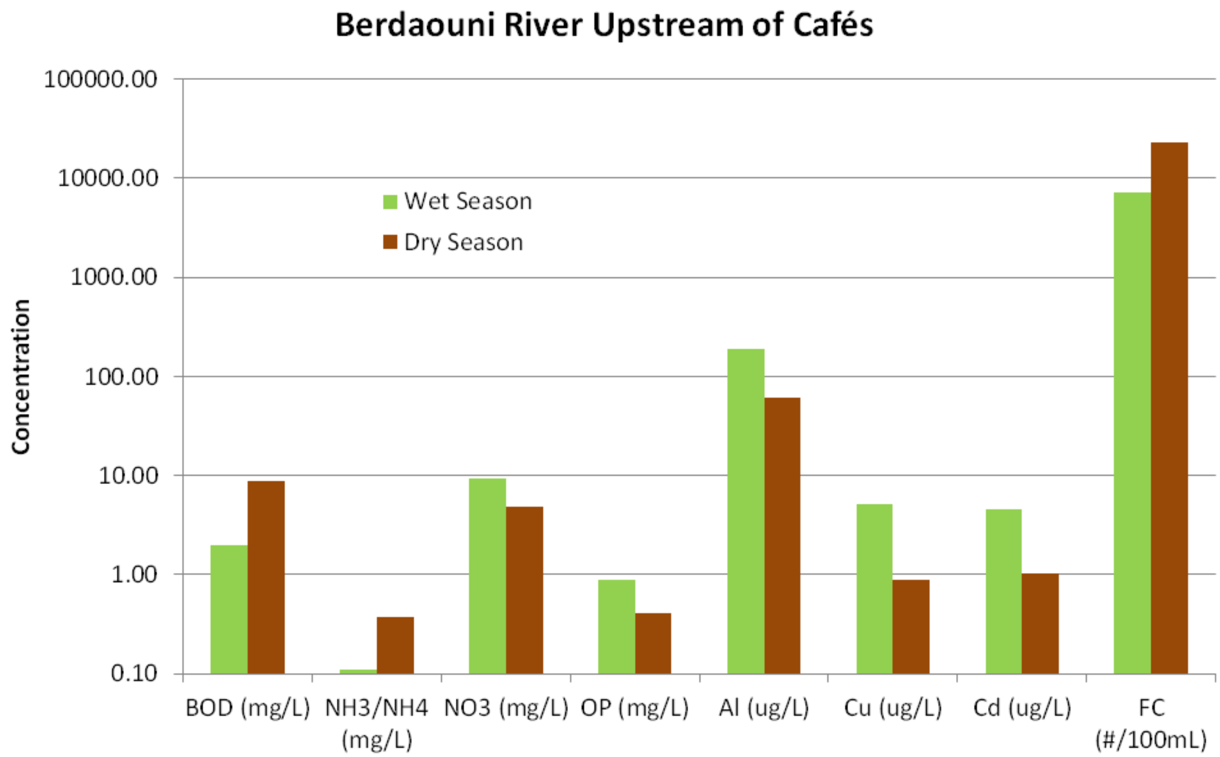

Figure 9: Summary of Water Quality Upstream of Berdaouni River Cafés

Note logarithmic scale; Al = Aluminum, Cu = Copper, Cd = Cadmium

selected for this analysis because its shape is more conducive for development of a treatment wetland and its larger size means a greater amount of flow can be treated.

The terrace treatment wetland requires a diversion upstream to develop sufficient hydraulic head to convey water to the terrace by gravity. This can be accomplished by installation of a small rubber inflatable dam in the river that when inflated creates a diversion structure and when deflated allows river flow to be conveyed without impairment (for example, when required in anticipation of a heavy rainfall event).

4.4.1.5. POTENTIAL TREATMENT EFFICIENCY

NewFields performed a preliminary analysis to predict treatment performance of a treatment wetland system constructed on the 3000 m² terrace along the Berdaouni River upstream of the cafés and assuming a diversion of 100 m^3/d. This likely represents a very small percentage of river flow during the winter but may be significant during the critical summer period.

Table 9 summarizes performance expectations for the proposed treatment wetland system as shown in Figure 10. Year-round removals of BOD greater than 50% and of fecal coliforms at 97% are possible. However, the levels of these two typical sewage pollutants do not by themselves explain the malodorous condition anecdotally described by owners of the cafés. Therefore, the available water quality data for the Berdaouni River may not accurately reflect the worst-case scenario conditions in the river at the cafés. If the malodorous condition is a result of decomposition of organic matter, and this exists in the Berdaouni River at greater levels than in the available data set, then reductions via wetland treatment of greater than 50% are possible and may have a significant impact on the problem.

While not impacting the cafés, toxic heavy metals (aluminum, cadmium, and copper) are present in the Berdaouni River and predicted removals are highest in the winter season and such removal would provide an ecosystem benefit downstream.

Pollutant	BOD (mg/L)	NO3 (mg/L)	OP (mg/L)	FC (#/100mL)	Al (ug/L)	Cd (ug/L)	Cu ug/L)
Winter Influent	7.9	9.3	0.9	7150	190	4.6	5.2
Winter Effluent	3.6	5.3	0.4	240	35	1.6	2.5
Winter % Removal	54%	43%	56%	97%	82%	65%	52%
Summer Influent	8.8	6.9	0.4	23000	61	1	0.9
Summer Effluent	3.8	<1	<1	700	4.6	<1	<1
Summer % Removal	57%	95%	0%	97%	92%	0-50%	0-50%

Table 9: Berdaouni River Terrace Treatment Wetland Performance Expectations

4.4.1.6. CONCEPT DESCRIPTION AND COST ESTIMATE

Figure 10 presents the layout for the proposed terrace treatment wetland system. The diversion structure would need to be approximately 100-150 m upstream of the upstream corner of the triangular terrace site. The terrace site would be bermed off and excavated as necessary to develop the treatment wetland. Discharge back to the river would be via an outlet structure and pipe appropriately stabilized adjacent to the river bed. The upstream cafés are just visible approximately 500-600 m downstream of the site.

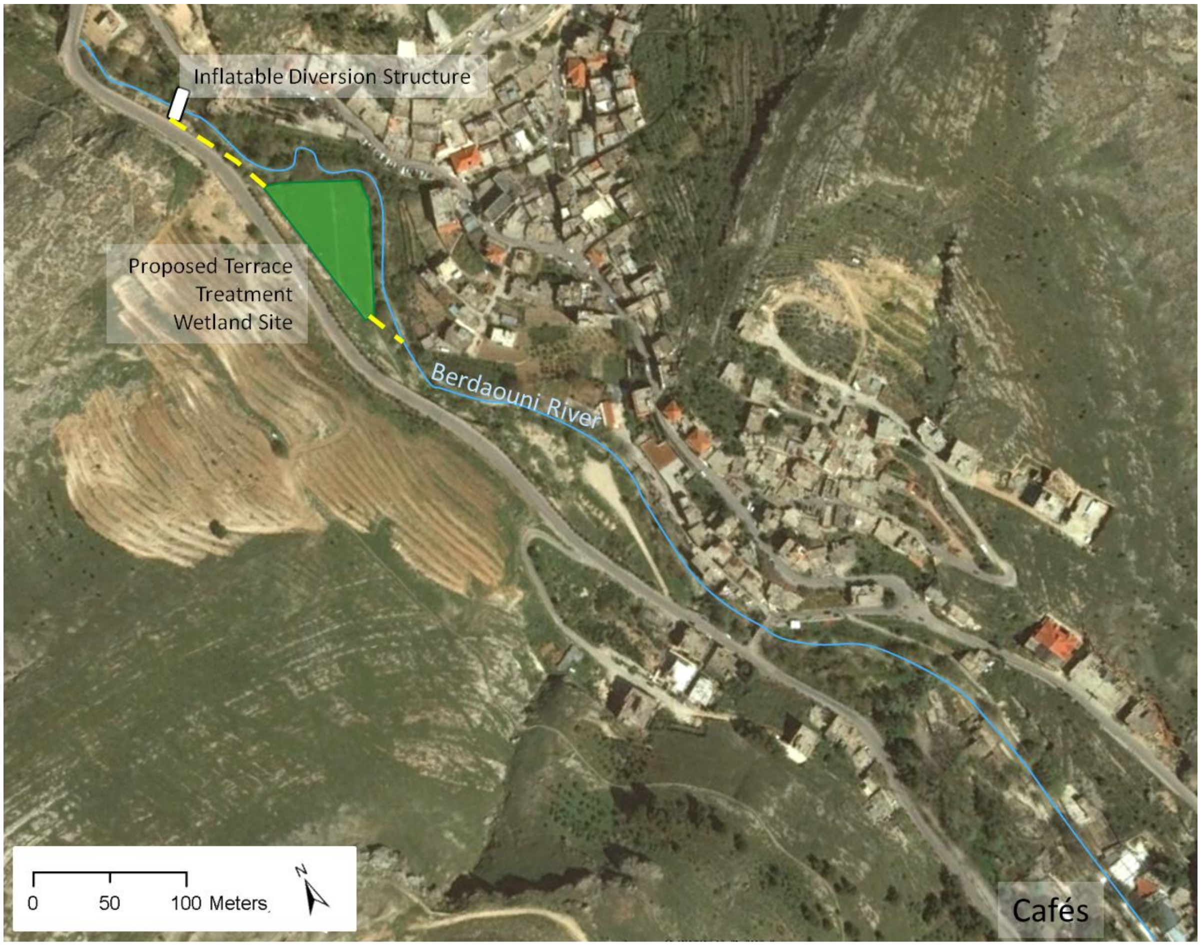

Figure 10: Concept Figure for Berdaouni River Terrace Treatment Wetland

A planning-level cost estimate for this treatment wetland is presented in Table 10. This cost estimate can be considered to have an approximate accuracy of +100/-50% which is consistent with the level of preliminary development of this treatment wetland concept.

Construction Item	Units	Unit Cost (US$)	Amount	Cost
Earthmoving	m^3	$ 6.75	2000	$ 13,500
Berms	m	$ 20.0	200	$ 4,000
Planting	ha	$ 15,000.00	0.3	$ 4,500
Piping and Structures	Lump Sum	NA	NA	$ 30,000
Contingency (30%)	Lump Sum	NA	NA	$ 15,500
Total				$ 68,000

Table 10: Preliminary Cost Estimate for Berdaouni River Terrace Treatment Wetland

5. RECOMMENDATION OF PREFERRED SITE AND JUSTIFICATION

For this feasibility analysis, NewFields evaluated four potential sites for development of a treatment wetland system in the Litani River Basin. All four sites were found to be feasible from an economic, technical, and engineering standpoint (and all could eventually be implemented over time for a substantial combined benefit for the Litani River Basin). However, we recommend implementation of the Joub Jannine wetland park for the following reasons:

- Land availability: this site is on public property with a substantial amount of available land.
- Polluted water access: this site has ready access to polluted Litani River water, Canal 900 irrigation water (derived from Qaraoun Lake and therefore of poor water quality itself), and is immediately downstream of a non-operational wastewater treatment plant that discharges untreated sewage into the Litani River.
- Public accessibility: much of this site may be readily accessed on foot from an existing LRA water management center with parking and other facilities.
- Opportunities for integration with a greater program of environmental education and stewardship: because this site is so close to the Aammiq wetlands, it presents a substantial opportunity to make the Bekaa Valley an important wetland education site where visitors may tour both natural and constructed wetland systems and learn about the vital roles they play in biodiversity, pollutant processing, flood attenuation, and other ecosystem services.
- Use of public funds for public good: while treatment of dairy wastewaters would provide an immediate and tangible benefit for the Litani River Basin, the Tannayel and Liban Lait dairies are private, for-profit companies with the resources to implement such measures on their own. Furthermore, siting a pilot treatment wetlands for the LRBMS on private land would not afford the same educational opportunities available at the Joub Jannine site.
- Monitoring: the LRA center has laboratory facilities in-house that could be readily used to analyze samples collected from the wetland system to validate its performance.

5.1. NEXT STEPS

To facilitate execution of design plans and specifications suitable for construction bidding and tender, the preliminary concept described in this document must be further refined into a conceptual design. This conceptual design should include the following features:

- detailed investigation of locations and characteristics of potential water sources including the Litani River itself, Canal 900 infrastructure, and the Joub Jannine wastewater treatment plant outfall
- development of a site water balance including analyses of precipitation and evaporation trends and infiltration estimates
- refinement of the sizing and layout to facilitate a more detailed cost estimate to ensure the construction of the largest possible wetland system within the available budget
- evaluation of and selection of pumping versus gravity diversion for conveying Litani River water to the site
- initial determination of materials and quantities for water conveyance, earthmoving, planting, water control structures, and bank stabilization
- development of layouts for visitor facilities (i.e., paths) and interpretive signs

It is anticipated that these next steps will be performed by NewFields and IRG and its associated local consultants.

5.1.1. DATA NEEDS

Additional data collection will be required to accomplish design of the preferred or any constructed treatment wetland system. While additional data may needs may become evident during the design process, the following data collection efforts should begin as soon as is realistically practical:

- Site topographic survey: a detailed topographic survey of the proposed wetland site, including the bathymetry of Litani River adjacent to the wetland site should be performed. To prepare for the potential for a diversion structure to convey Litani River water to the site by gravity, additional surveying should be performed extending upstream past any potential diversion site. Selection of a diversion site may require additional reconnaissance by IRG and its local associated consultants.
- Site infiltration and soil testing: to complete a detailed water balance for the site, it is important to estimate expected infiltration rates into groundwater from the wetland. A qualified hydrogeologist should also inspect the local soils in case they have the potential for seasonal variability in infiltration that may not be able to be assessed prior to completion of the design package (for example, expansive/contractive clay soils that exhibit highly varying infiltration rates depending on their moisture content).

- Mosquito surveillance: if the presence of mosquitoes at the site or any increase in populations due to wetland construction are a concern, mosquito populations in the area should be surveyed as a baseline (with equipment such as the BG-Sentinel http://www.bg-sentinel.com/) prior to construction of any wetland system.

- Cost estimating consultation: if possible, consultation with local contractors (especially if there is existing preferred local contractor for this type of construction) is important to understand local cost factors and materials availability for the major activities associated with this type of project such as earthmoving, planting/hydroseeding, piping/conveyance, pumps and associated materials, riverbank stabilization, etc.

6. CONCLUSION

The proposed treatment wetland at the Joub Jannine site is anticipated to be able to treat up to approximately 1500 m^3 /d during the dry season, which may be a significant portion or even all of the available flow in the Litani River. However, even at an expanded flow rate of approximately 3000 m^3/d during the wet season, this wetland system would be treating as little as 0.02% of the average daily flow in the Litani River. Because it is a pilot system and will be Lebanon's first constructed treatment wetland, its purpose is more for demonstration of the technology, environmental education, and use as a building block and technology transfer toward further expansion of this technology in the Bekaa Valley and around Lebanon. Therefore, it is not expected that this system alone will have a significant impact on water quality in the Litani River Basin as a whole. However, a large-scale implementation could indeed have a meaningful and lasting impact on water quality, aquatic ecosystem habitat, and attitudes of the local population towards their water resource.

An immediate potential location for larger scale implementation is the LRA property proposed for this project pilot wetland. With approximately 100 hectares available, more land is available for wetlands development then the readily available supply of water could support; expansion of wetlands in this property is a logical next step. However, with so many individual point-source polluters in the Litani River Basin such as dairies, industrial facilities, and wastewater outfalls, a significant, tangible water quality improvement could be realized by implementation of these systems methodically at numerous locations throughout the basin.

REFERENCES

Kadlec, R and S. Wallace. 2009. *Treatment Wetlands*. Second Edition. CRC Press: Boca Raton, FL.

LRBMS 2010. Litani River Flood Field Survey Report. Prepared by IRG. August 2010.

Litani River Basin Management System (LRBMS). 2011a. Litani River Basin Management Plan: Draft, Volume 1 – Current Situation. Prepared by IRG for USAID. Draft December 2011.

LRBMS. 2011b. Trip Report – Lebanon, January 2011. Prepared by Robert W. Hill, Utah State University. 22 January 2011.

LRBMS. 2011c. Feasibility study for the management of the industrial wastewater effluents of the Liban Lait dairy plant. Prepared by IRG. August 2011.

LRBMS. 2012a. Personal Communication with Fadi Karam and Hussam Hawwa, 16 February 2012. Precipitation data from Bekaa Valley in MS-Excel spreadsheets.

LRBMS. 2012b. Personal Communication with Eric Viala, 25 January 2012. Water quality compendium from multiple sources in MS-Excel spreadsheet.

SPI-Water. 2007. Description of the selected non-EU river basin Litani (Lebanon). Deliverable 20A, 11 December 2007.

United Nations Development Programme (UNDP) 2011. Business plan for combating pollution of the Qaraoun Lake. Prepared by Earth Link and Advanced Resources Development S.A.R.L. (ELARD). 13 June 2011.

7. APPENDIX A: FEBRUARY 2012 TRIP REPORT

NewFields contract with IRG for support of LRBMS activities related to development of a constructed treatment wetland system for improvement of water quality in the Litani River Basin includes two staff trips to Lebanon. The first occurred between 22 January and 4 February 2012 by Paul Frank, P.E.

Purpose

The primary purposes of the trip included:

- Enable NewFields to become familiar with Beirut-based IRG staff and related consultants,
- tour potential wetland sites within the Litani River Basin to assess their general viability for construction of a treatment wetland,
- obtain data necessary to complete a feasibility report for constructed treatment wetlands in the Litani River Basin, and
- present preliminary findings in-person to LRA staff.

Summary of Activities

The trip was divided between time spent in the LRA offices in Beirut and time spent in the field in the Bekaa Valley. Office worktime focused on data acquisition, review of reports, engaging LRA, IRG, and related staff with information or expertise relevant to the task at hand and the presentation to LRA staff. Field worktime focused on gaining a hands-on understanding of the Bekaa Valley, its water quality problems, and its hydrologic and hydraulic context as well as meeting with potential partnering entities within the Valley for development of the constructed treatment wetlands. Key dates of activities are as follows:

Tuesday, 24 January: first visit to the Bekaa Valley. Visited municipal governments in the cities of Jdita and Zahle. Met with local farmer to discuss agriculture in the Valley and its environmental and economic impacts. Toured LRA property near Joub Jannine including laboratory/office center and the land between the center and the Litani River. Visited on the Aammiq wetlands.

Friday, 27 January: second visit to the Bekaa Valley. Visited Berdaouni River cafés as well as potential wetland sites upstream. Visited the Litani River and Berdaouni River locations within the city of Zahle and related trash dump/sewer discharge sites. Visited Chamsine natural springs and Kfar Zabad nature reserve. Toured Taanayel dairy farm/vineyards/ecotourism site to assess feasibility for treatment of dairy wastewater in a treatment wetland.

Thursday,2 February: presentation on treatment wetlands and their applicability to the Litani River Basin given to LRA staff at LRA offices.

Friday,3 February: third visit to the Bekaa Valley. Visited Qaraoun Lake area. Revisited Joub Jannine LRA property. Toured Liban Lait dairy factory and farm to evaluate potential for treatment of wastewater in a treatment wetland.

Outcomes

This trip resulted in the following key outcomes:

- Obtained and catalogs numerous reports and data files useful and feasibility assessments and design of the eventual wetland. A list of these can be found in the References section in the main text of this report.
- Through field visits and conversations with IRG, LRA, and related staff, a preferred wetland site was selected – near Joub Jannine and the existing LRA Center.
- The presentation on treatment wetlands and their applicability to the Litani River Basin was made to LRA staff.
- Reviewed existing HEC-RAS model of the Litani River system for its effectiveness as a predictive tool of flood risk. This model will also be useful for determination of expected Litani River water surfaces near the proposed treatment wetlands site. For this reason, recommended improvements should be made to the model to potentially increase its accuracy.
- A proposed schedule for completion of treatment wetlands design and construction scheduling was developed and is described in the main text of this report.

U.S. Agency for International Development
1300 Pennsylvania Avenue, NW
Washington, DC 20523
Tel: (202) 712-0000
Fax: (202) 216-3524
www.usaid.gov